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Structural and Physical Aspects of Construction Engineering

Lateral Torsional Buckling of Selected Cross-Section Types

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Abstract

Currently used methods of solution of Lateral Torsion buckling which are implemented in design codes are based on solution of critical moment. This method can be correctly used only for minimally single symmetric cross sections. Also FEM based numerical models cannot be generally used because of problematic specification of all imperfections. Usually it is very difficult to define all boundary conditions and also effect of loading during the iteration process.
The goal of presented research is an experimental and theoretical analysis of selected types of cross-sections of elements subjected to bending with focus on lateral torsional buckling problems. Those experiments are focused on differences between real behaviour of single symmetric cross section and slightly non symmetric cross section.

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Keywords: Experiment; Bendig; Lateral Torsional Buckling; Stability

1. Introduction

The term lateral torsion stability of transversely loaded beam is a specific type of general buckling. In a case where the beam is loaded in the plane of main stiffness and together the transverse deflection along the beam length is not prevented, the deflection transverse to initial bending plane gradually rises. In principle it is a general stability problem of transversely loaded beam, which is characteristic by spatial deformation covering the flexural bending and the torsional displacement. The compressed part of the cross section is inclinable to deviate in the direction of minimal resistance. The tensioned part of the cross section stabilize the stiffness of cross section and inflicts the torsional displacement. This is similar to axially loaded beams.

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1.1. Problem definition

The problem of lateral torsional stability during the bending is a stabile problem, which can be described by two differential equations of fourth order [1]; [2]. The solution of these equations is the value of the critical bending moment. This critical bending moment is used in methods which are nowadays implemented in normative documents. These methods are useful only for cross sections which are at least single symmetric.

Often there is a need to use non symmetric cross section for bended member in practical steel structure design. Design methods implemented in normative documents it therefore difficult to use [3].

One of the possibility how to solve such transversely loaded beam with general non symmetric cross section is to use geometrically nonlinear solution of stability. All imperfections has to be implied in the solution. For example by substitution of initial imperfection [4].

Another way is the solution with the use of 3D numerical models. The use of this method is also difficult due to problematic implementation of imperfections. The differences between real structure and numerical model are often hard to describe. Modelling of real behavior of real boundary conditions, load position changes during the process of loading, and implementation of all imperfection is very difficult task.

1.2. Goal of analysis

This paper is focused on experimental analysis. Several experiments were realized to obtain the real measurable data which can be further compared to numerical models and theoretical studies. Geometry of all specimens was prepared with the idea to observe the difference in behavior of monosymmetric and slightly asymmetric cross section.

2. Experiments and comparison of results

The four point bending tests were prepared to observe the lateral torsional behavior of different cross section. Material used for all specimens was the steel S235. Laboratory verified characteristic of used steel are: yield strength $f_y = 327\ MPa$ and ultimate strength $f_u = 458\ MPa$. For each configuration, see Fig. 1 and Fig. 3(a) the number of five tests are planned (marked as H1A to H4E). So far only specimens marked as H1 (A to E) and H4 (A to E) were tested. Those results are described below.

2.1. Experiment configuration

Tested specimens were prepared according to geometry displayed in Fig.1. The beam is loaded in two points in the third of length. The length of specimens was 3000 mm and the distance between hinge joints in the loading system was 3170 mm. There were four strain gauges installed at both ends of both flanges (marked as T1, T2, T3 and T4).

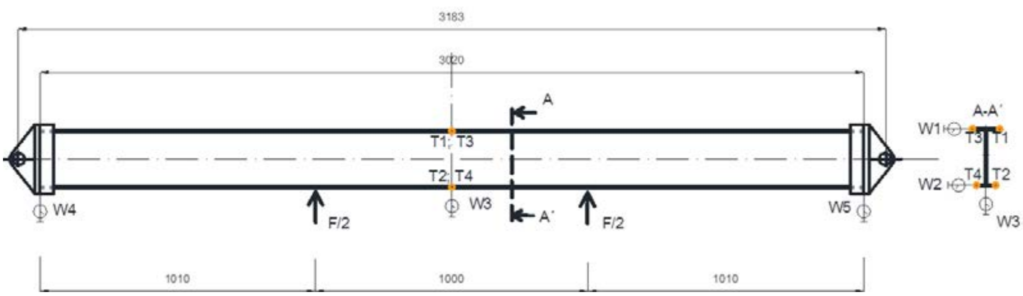

Fig. 1. Geometry of the specimen.

Each strain gauge was placed in the middle of the flange. The applied force and also the displacement of five points was measured. Deformation in both supports and in the middle of the span were measured to obtain the vertical deflection of beam (W3, W4 and W5). The displacements of both top and bottom flange in transversal direction (W1 and W2) were measured to obtain the rotation of the cross section in the middle of the span too. Potentiometer pick offs WPS-250-MK30-P10 and inductive picks HBM WA10-T were used for measuring deformations. All strain gauges were the same type HBM LY11 3/350. All data were measured by HBM MGC+ station.

The picture of whole experiment configuration is in Fig. 2(a). Fig. 2(b) shows the specimen deformation during the loading process.

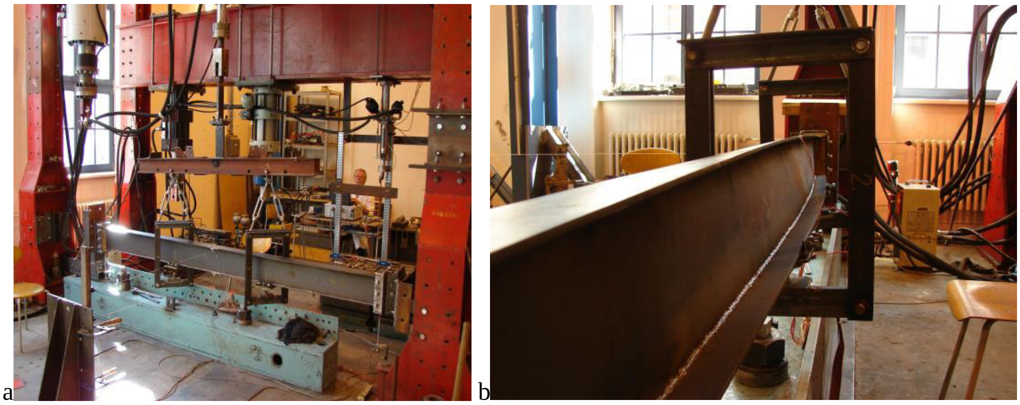

Fig. 2. (a) Experiment configuration; (b) Beam deformation during the experiment.

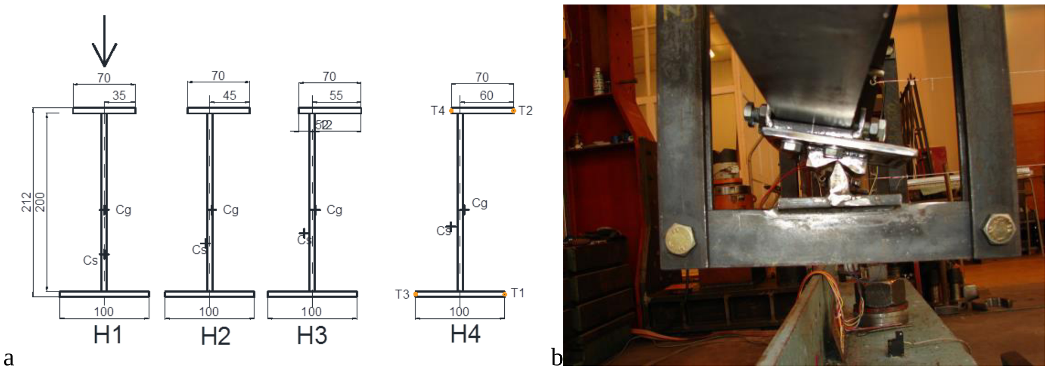

Fig. 3. (a) Geometry of C-sections – Specimen prepared for test; (b) Load application (in the center of the web).

The force was applied in the middle of the web as it is displayed on Fig. 3(b). Therefore also initial eccentricity between the applied force and the center of shear was also measured.

There are results for one specimen of H1 and one specimen of H4 presented in following figures. Fig. 4 show results for single symmetric cross section. The black thick curve represents the stress measured by strain gauges. The dot and dash green line is the applied force. The thin blue line represents the calculated value of normal stress from biaxial bending, in each point this value was calculated for actually rotated main axes. Thin dashed line represents the calculated value of normal stress from warping moment caused by torsion. The thick red dashed line is the calculated value of normal stress (a sum of the bending and torsion action). For the single symmetric cross section the force was applied in the center of shear at the beginning of loading procedure. Therefore there is no torsion caused by initial eccentricity. For non-symmetrical cross section there was a small eccentricity because the load was applied in the middle of the cross section web. In Fig. 5 there is value of normal stress from warping moment caused by torsion from the initial eccentricity marked by thin dotted line. This value is also implemented in the global value of stress caused by warping moment. The divergence between those two values is the effect of latter torsional stability.

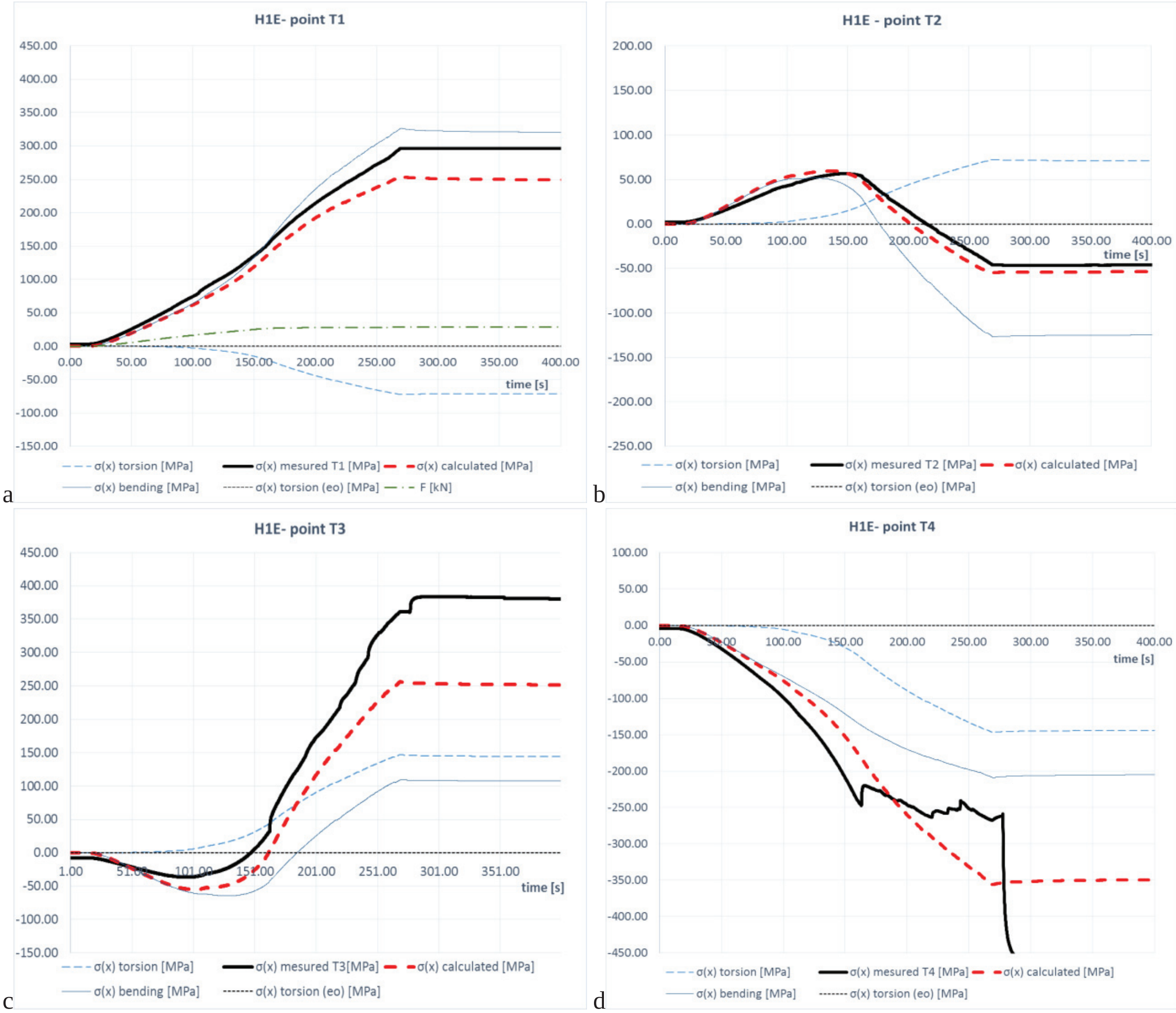

Fig. 4. Data measured on H1E specimen a) strain gauge T1; b) strain gauge T3; c) strain gauge T2; d) strain gauge T4.

3. Conclusion

Results presented in Fig. 4 and Fig 5. represent only the pilot set of experiments. Only one from the number of five test are presented in this paper. Results of all test H1A to H1E as well as H4A to H4E were very similar. So far only specimens H1 and H4 were testes. These results and also the results of H2 and H3 specimens will be used for further analysis. As it is obvious from presented results the normal stress on both cross sections is the subject of the same rules. In fact it is a combination of stresses inflicted by bending and the torsion caused by the cross section torsional displacement. One of the goal is to find the function of the torsional displacement of non-symmetrical cross section coherent to lateral torsional stability problem. These experiments will serve as a base for further numerical and theoretical research. The global aim is to describe the lateral torsional stability for the beam with non-symmetrical cross section.

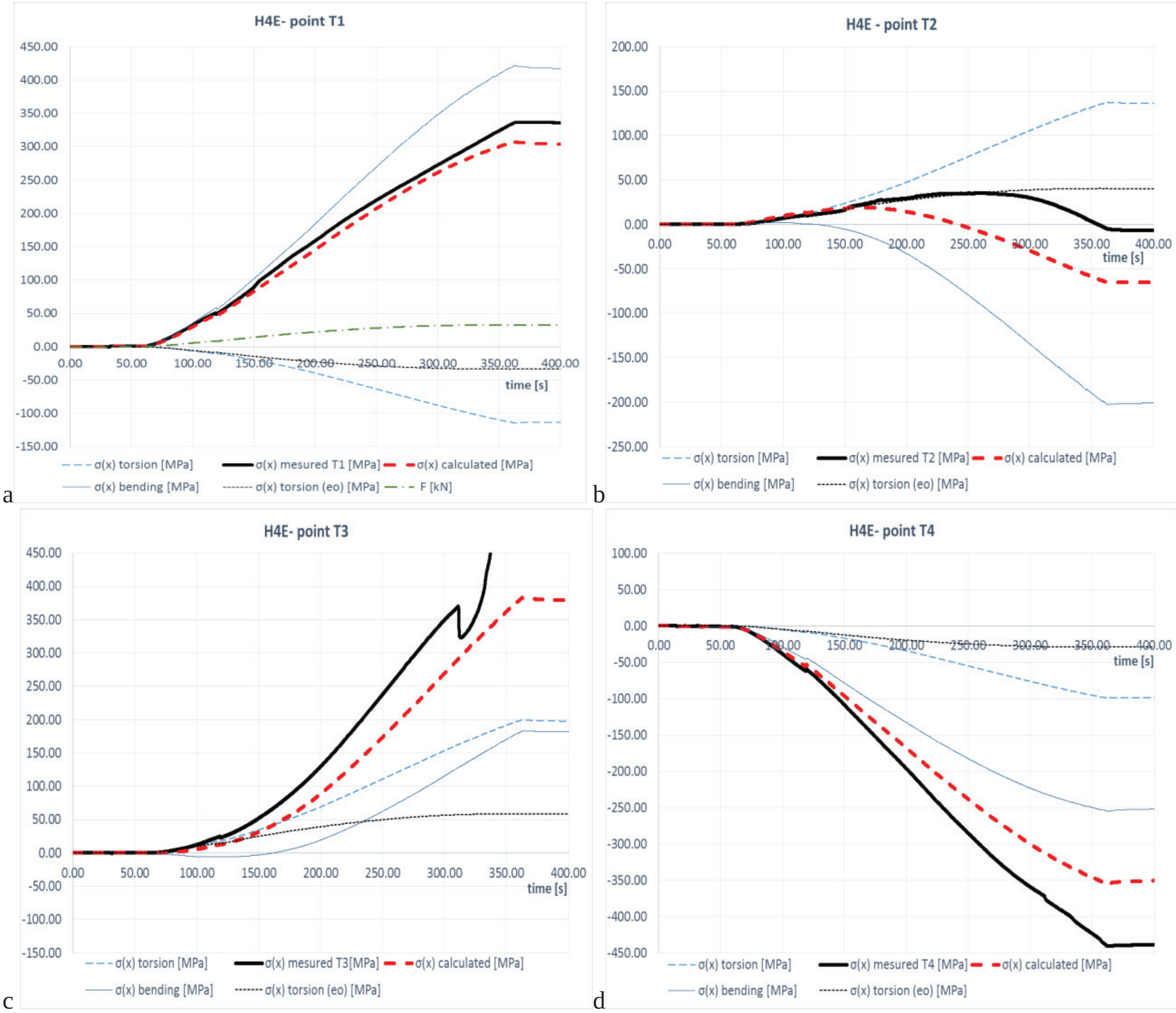

Fig. 5. Data measured on H4E specimen; a) strain gauge T1; b) strain gauge T3; c) strain gauge T2; d) strain gauge T4.

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